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# EFFECTS OF ATMOSPHERIC DEPOSITION ON SULFUR AND NITROGEN CONTENT OF FOUR URBAN TREE SPECIES[1]

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**Abstract.** One-yr.-old containerized seedlings of black locust, black cherry, Siberian elm, and yellow-poplar were fumigated with either $SO_2$, $NO_2$ or with a combination of both pollutants 7 hr daily for 8 weeks under controlled conditions. Tissue samples were analyzed for sulfur and total nitrogen content at the end of the experiment. Sulfur content of black locust and yellow-poplar seedlings fumigated with $SO_2$ was always greater than comparable seedlings without $SO_2$. However, nitrogen content of seedlings exposed to $NO_2$ was no greater than similar plants grown in the absence of $NO_2$. It appears that fumigation with a combination of both pollutants inhibited sulfur uptake of black locust and black cherry seedlings, and increased nitrogen accumulation in Siberian elm and black cherry seedlings.

Currently, there are three gaseous pollutants of primary concern with respect to their potentially harmful effects on vegetation in North America. Two of these pollutants, sulfur dioxide ($SO_6$) and nitrogen dioxide ($NO_2$), are ubiquitous across the continent and serve as precursors to acid precipitation (8). Because of the anticipated increase in anthropogenic emissions of these pollutants from transportation sources and large megawatt coal-burning power plants, deposition of gaseous pollutants will continue to have an influence on plant growth and development. This is especially true in light of the widespread distribution of polluted air masses from high stacks and related industrial activities that affect vegetation at considerable distances from the source (8).

Vegetation has been suggested as a natural filter or sink for gaseous contaminants ever since studies first reported by Thomas and Hill in 1935 (17). Subsequently, numerous investigations with herbaceous and woody plants have substantiated the potential ability of vegetation to act as a reservoir for gaseous and particulate contamination (4, 5, 7, 10, 11, 14, 15, 19). If, as suggested by these studies, vegetation does constitute an important sink for atmospheric pollutants, then woody plants could play a major role in this phenomenon. Not only do forests occupy more than one-third of the land area of the continental U.S. (12), but trees and woody shrubs represent the dominant vegetation types in densely populated urban and suburban areas where ambient pollution levels tend to be high.

There is unquestionably a need for additional information on the deposition process and the capability of urban vegetation to modify existing levels of atmospheric contamination. This study was designed to investigate the deposition of $SO_2$ and $NO_2$ and its subsequent effect on the elemental sulfur and nitrogen content of four woody plant species.

### Materials and Methods

One-yr.-old dormant seedlings of black locust (*Robinia pseudoacacia*), black cherry (*Prunus serotina*), Siberian elm (*Ulmus pumila*) and yellow-poplar (*Liriodendron tulipifera*) were planted in

[1]Mention of a trademark or proprietory product does not constitute a guarantee or warranty of the product by USDA, and does not imply its approval to the exclusion of other products that may be equally suitable.

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15-cm plastic containers in a potting media containing bog soil and sand (2:1), and placed in a preconditioned environmental chamber (25/20 C day/night thermoperiod; 50 ± 10% relative humidity; 16 hr photoperiod at 250 $Em^{-2}S^{-1}$ photosynthetically active radiation, PAR). During this pretreatment period, all seedlings were watered thoroughly as required and fertilized biweekly with 100 ml of commercial fertilizer solution containing nitrogen, phosphoric acid and soluble potash (20-20-20). When 60 seedlings of each species had broken dormancy, 15 plants were randomly assigned to one of the following fumigation treatments: 1) 0.1 ppm $SO_2$; 2) 0.1 ppm $NO_2$; 3) 0.1 ppm $SO_2$ + 0.1 ppm $NO_2$; 4) control. Fumigations of black cherry, Siberian elm and yellow-poplar were conducted in a single pass chamber system similar to that described by Heck et al. (9). Fumigation of black locust seedlings was carried out in chambers similar to those described by Wood et al. (20).

Environmental conditions during fumigation were the same as those previously mentioned. Seedlings of black locust were fumigated 7 days each week. Black cherry, Siberian elm and yellow-poplar seedlings were fumigated only 5 days per week. All plants were fumigated for 7 hr every day over a period of 8 weeks. During fumigation, $SO_2$ and/or $NO_2$ were added to a charcoal-filtered air stream and were sampled automatically in each chamber at 20 minute intervals. Sulfur dioxide was sampled with a Beckman model 90 A $SO_2$ analyzer, and $NO_2$ with a Monitor Labs model 8840 Nitrogen Oxides analyzer. Experiments with black locust and black cherry seedlings were conducted once; those involving Siberian elm and yellow-poplar seedlings were repeated a second time.

Following the 8 week fumigation period, the leaves, stems, and roots of each seedling were oven-dried at 100 C for 48 hr and ground together in a Wiley mill to pass a 40-mesh screen. From this dried plant tissue, individual 0.1 g samples were taken for sulfur and nitrogen analyses. Each sample was analyzed for sulfur content using a modification of the iodometric sulfur determination described by Bremanis et al. (3), and for total nitrogen content using an automated Keldahl nitrogen technique (1).

**Results and Discussion**

The sulfur and nitrogen content of seedlings fumigated with $SO_2$, $NO_2$, and a combination of both pollutants is found in Tables 1 and 2, respectively. Since the primary way in which vegetation removes gases from the atmosphere is by stomatal absorption, it was expected that the sulfur and nitrogen content in plant tissue exposed to $SO_2$ or $NO_2$ would be greater than comparable tissue grown in the absence of these pollutants. Although this relationship was true for black locust and yellow-poplar seedlings fumigated with 0.1 ppm $SO_2$ (Table 1), it was not true for any of the species fumigated with 0.1 ppm $NO_2$ (Table 2). The nitrogen data were unexpected, but may be explained by the different rates at which $NO_2$ is metabolized. Tingey (18) has reported $NO_2$ uptake in various herbaceous plants can change from a linear to a nonlinear relationship as the length of exposure to the pollutant increases. The concentration of $NO_2$ during fumigation may also influence the amount of uptake (13).

The quantity of elemental sulfur in black locust and yellow-poplar seedlings fumigated with $SO_2$ alone was always greater than in unfumigated (control) plants of the same species (Table 1). For seedlings fumigated with a combination of $SO_2$ + $NO_2$, the sulfur content was either the same (Siberian elm and yellow-poplar) or significantly less (black locust and black cherry) than for comparable plants exposed to $SO_2$ alone (Table 1). These results were unexpected and suggest the possibility of an antagonistic or inhibitory effect on sulfur absorption by certain species when contaminants other than $SO_2$ are present. Elkiey and Ormrod (6) reported similar findings for petunia plants exposed to combinations of $SO_2$ and ozone. As expected, there was no effect of $NO_2$ fumigation on the sulfur content of any of the species used in this study, i.e. no significant difference in sulfur content was found among plants fumigated with $NO_2$ only and among those receiving no fumigation (Table 1).

For the species used in this study, yellow-poplar was found to have the highest endogenous level of sulfur, followed by black locust, elm and black cherry (Table 1). In general, these results agree with published values for these species

**Table 1. Sulfur content of 0.1 g oven-dried samples from one-yr.-old containerized tree seedlings fumigated with 0.1 ppm $SO_2$, 0.1 ppm $NO_2$ or a combination of 0.1 ppm $SO_2$ + 0.1 ppm $NO_2$ 7 hr daily for 8 weeks.[1]**

| | Sulfur content (%)[2] | | | |
|---|---|---|---|---|
| *Fumigation treatment* | *Black locust* | *Black cherry* | *Siberian elm* | *Yellow-poplar* |
| $SO_2$ | 0.756$^c$ | 0.182$^c$ | 0.232$^{ab}$ | 0.763$^{bc}$ |
| $NO_2$ | 0.406$^a$ | 0.145$^b$ | 0.189$^a$ | 0.672$^{ab}$ |
| $SO_2 + NO_2$ | 0.623$^b$ | 0.095$^a$ | 0.268$^b$ | 0.666$^{ab}$ |
| Control | 0.366$^a$ | 0.159$^{bc}$ | 0.185$^a$ | 0.582$^a$ |

[1]Environmental conditions during fumigation: 25/20 C day/night thermoperiod; 50 ± 10% relative humidity; 16-hr photoperiod at 250 E $m^{-2}s^{-1}$ PAR.

[2]Each value represents the mean of either 15 seedlings (black locust and black cherry) or 30 seedlings (Siberian elm and yellow-poplar). Mean separation within columns by Duncan's new multiple range test, P = 0.05. Seedlings of Siberian elm, yellow-poplar, and black cherry fumigated 5 days weekly; seedlings of black locust fumigated 7 days weekly.

**Table 2. Total nitrogen content of 0.1 g oven-dried samples from one-yr.-old containerized tree seedlings fumigated with 0.1 ppm $SO_2$, 0.1 ppm $NO_2$ or a combination of 0.1 ppm $SO_2$ + 0.1 ppm $NO_2$ 7 hr daily for 8 weeks.[1]**

| | Nitrogen content (%)[2] | | | |
|---|---|---|---|---|
| *Fumigation treatment* | *Black locust* | *Black cherry* | *Siberian elm* | *Yellow-poplar* |
| $SO_2$ | 3.537$^a$ | 2.504$^a$ | 2.882$^{ab}$ | 2.097$^b$ |
| $NO_2$ | 3.831$^b$ | 2.660$^a$ | 2.771$^a$ | 1.691$^a$ |
| $SO_2 + NO_2$ | 3.520$^a$ | 3.323$^b$ | 2.951$^b$ | 1.695$^a$ |
| Control | 3.917$^b$ | 2.582$^a$ | 2.852$^{ab}$ | 1.774$^a$ |

[1,2]See footnotes for Table 1.

(16). Comparing the sulfur content of $SO_2$ fumigated and unfumigated seedlings (Table 1), black locust appears to be the most effective sink plant among the species tested in these experiments. Sulfur contents more than doubled in black locust seedlings over the 8 week fumigation period, while it increased only 14 to 31% for the remaining three species. However, yellow-poplar, elm, and cherry were fumigated only 5 days per week while black locust was fumigated 7 days each week.

As stated previously, the total nitrogen content of seedlings fumigated with $NO_2$ was no greater than similar seedlings without $NO_2$ (controls). In this respect, the species used in this study were less effective as nitrogen sinks in atmospheres containing $NO_2$ than they were as sulfur sinks in atmospheres containing $SO_2$. When a combination of both pollutants was used, the nitrogen content of Siberian elm and black cherry seedlings was actually higher than it was for similar seedlings fumigated with $NO_2$ only (Table 2). These results are unlike those observed for sulfur uptake, where the data suggested a possible competitive effect between the two pollutants. For nitrogen uptake, the data indicate the possibility of an additive effect when plants are fumigated with both pollutants together. One possible explanation for these results may be the influence of $SO_2$ on stomatal opening. Stomatal conductance has been shown to increase for certain woody plants in the presence of $SO_2$ (2), and this increase in stomatal opening may be sufficient to allow for the absorption of additional $NO_2$.

The data from this study present additional evidence to suggest that trees have considerable potential to filter gaseous pollutants from the atmosphere. There is a need for additional research to identify the species which can function effectively in the capture and recycling of atmospheric contaminants. As yet we lack the necessary quantitative data to demonstrate that trees are capable of significantly reducing air pollution levels below the threshold values which harm urban vegetation.

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## Abstract

ANONYMOUS. 1985. **High saline conditions are tough on trees.** Arbor Age 5(8):20-22.

Although salt may not spring immediately to mind when compiling a list of tree enemies, it can be a killer. Trees that are subjected to excess salts, whether those salts are in the soil or on the foliage, will suffer leaf scorch, defoliation, stunted growth, and ultimately, death. Large amounts of sodium chloride are used each winter to deice the roadways. The salt, often mixed with sand or other gritty materials to promote uniform distribution, usually ends up in the soil or on foliage. Fortunately, a saline soil condition is far more easily corrected than other adverse environmental conditions. Since most harmful salts are water soluble, careful applications of water will effectively leach the salts out of the root zones. A general formula suggests that for each foot of medium-texture soil that is being leached, one should apply six inches of water to leach out about half the soluble salts, 12 inches of water to leach out about four-fifths of the soluble salts, and 24 inches of water to leach out about nine-tenths of the soluble salts. One problem that plagued arborists in the past was a tendency to attribute salt-related problems to other factors. However, there is now an increasing awareness within the industry of the damage that excessive salinity can do to trees.